U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 240.

INOCULATION OF LEGUMES.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief.
Washington, D. C., November 29, 1905.

Sir: I have the honor to transmit herewith a paper entitled "Inoculation of Legumes," and to recommend that it be published as a Farmers' Bulletin. This paper was prepared by Mr. Karl F. Kellerman, Physiologist in Charge of the Laboratory of Plant Physiology, and Mr. T. R. Robinson, Assistant in Physiology in the Office of Vegetable Pathological and Physiological Investigations, and was submitted by Mr. Albert F. Woods, the Pathologist and Physiologist, with a view to publication.

Special attention is called to the method of distributing bacteriologically pure cultures in a nitrogen-free nutrient solution in hermetically sealed tubes. Laboratory tests show that cultures of this kind may be readily handled and shipped and that they possess advantages over cultures dried on cotton.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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INOCULATION OF LEGUMES.

INTRODUCTION.

The method of distributing practically pure cultures of nitrogen-fixing bacteria dried on cotton has not proved entirely satisfactory, owing to varying conditions of air during transit in the mails and to certain matters connected with laboratory technique. While the number of unsuccessful attempts to secure inoculation by users of cotton cultures sent out by the Department of Agriculture is small, it has been recognized that the methods of preparing the organisms and distributing them were open to improvements. Investigations have been under way for some time with a view to improving the methods followed, and as a result the Department is now prepared to send out bacteriologically pure cultures in small tubes hermetically sealed.

The experiments carried on by the Department of Agriculture have demonstrated the fact that by the proper use of practically pure cultures the nodule-forming bacteria are actually carried into the soil. These bacteria are able to form root nodules, and where other conditions are favorable the inoculation thus brought about makes possible the growth of a legume in soils where it had failed previously from lack of bacteria. The original cultures used, however, must be prepared with the utmost care and with a view to preserving or increasing their natural power of nitrogen fixation rather than merely to make them grow under favorable conditions.

DIRECTIONS FOR USING CULTURES.

The following directions will accompany the packages distributed under this new plan:

TO PREPARE THE CULTURE LIQUID.

Put 1 gallon of clean water (preferably luke-warm rain water) in a clean bucket or jar and add 3 heaping teaspoonfuls of granulated or brown sugar; then add the tablet contained in the small envelope No. 1. Allow all to dissolve, stirring with a clean rod or spoon if necessary.

Carefully open package No. 2, breaking off the top of the glass tube, being careful not to spill the liquid, and pour the contents into the solution. Cover

the bucket with a paper or moist cloth to protect from dust, and set aside in a warm place for twenty-four hours. About 70° F. is the best temperature. Do not heat the solution or you will kill the bacteria; it should never be as warm as blood heat.

After twenty-four hours add the tablet in envelope No. 3 and allow the mixture to stand another twenty-four hours. The liquid should now be faintly cloudy and ready for use. If sufficient growth has not taken place to bring about this cloudiness, further time should be given, not to exceed two days.

TO INOCULATE SEED.

Take just enough of the solution to moisten the seed (1 gallon will moisten 2 bushels of seed). Stir thoroughly, so that all the seeds will be touched by the solution. Spread out the seeds in a shady place, rake over occasionally until dry, and plant just as you would untreated seed. If bad weather should prevent planting at once, the inoculated seed, thoroughly dried and properly stored, may usually be kept without deterioration for several weeks.

TO INOCULATE SOIL.

Take enough dry soil so that the solution will merely moisten it. Mix thoroughly, to moisten every particle, and mix this with four or five times as much—say half a wagonload. Spread this inoculated soil thinly and evenly over the prepared ground exactly as if spreading fertilizer. The inoculated soil should be harrowed in immediately.

Either of the above methods may be used as convenient.

INFORMATION FOR USERS OF INOCULATING MATERIAL.

The inclosed package, marked "No. 2," contains a pure liquid culture of bacteria. This culture treated according to directions will produce a liquid culture which, if associated with the proper plants, is capable of rendering available to these plants the free nitrogen of the air. This is accomplished through the formation of root nodules.

The bacteria are capable of making up for a deficiency of soil nitrogen, but where other elements, such as potash and phosphoric acid, are lacking, inoculation will not do away with the necessity for fertilizers containing these substances. Mineral fertilizers, however, should never be applied so as to come into direct contact with inoculated seed. The action of concentrated fertilizers drilled with inoculated seeds is injurious; this is especially true if the seeds should be still moist after treating with liquid culture. Floors used for drying inoculated seeds should be thoroughly scrubbed and rinsed, especially if the same floor space has served for mixing fertilizers. The liquid on the seeds is able to dissolve chemicals contained in the fertilizers, and the effect might be disastrous alike to seeds and bacteria. Moistened seeds should never be dried by mixing with pulverized fertilizers; if it seems desirable to hasten drying, clean sand or dirt is the best material to use. Fertilizers should be spread and mixed with the soil or drilled previous to sowing the seed, and if the drill has been used for this purpose all parts with which the seeds may come in contact should be cleaned.

This material is furnished you with the understanding that you will carefully follow instructions in its use and will report your success or failure to secure good inoculation. Note the presence or absence of nodules on the roots of inoculated and uninoculated plants.

WHEN INOCULATION IS DESIRABLE.

(1) If a soil is low in organic matter and has not previously borne leguminous crops.

(2) If legumes previously grown on the same land were devoid of nodules.

(3) If the legume to be sown belongs to a species not closely related to one previously grown on the same soil.

WHEN INOCULATION MAY PROVE ADVANTAGEOUS.

(1) If the soil produces a sickly growth of legumes, even though their roots show some nodules.

(2) If a leguminous crop has made a stand but gives evidence of failure, due to the absence of root nodules. Under such conditions it is advisable to apply the culture liquid by spraying or, better, by top-dressing the land with soil moistened with the culture liquid, as explained in the directions.

WHEN INOCULATION IS USELESS.

(1) If the legumes usually grown are producing average yields or the roots show nodules in abundance.

(2) If the soil is rich in nitrogen. It is neither necessary nor profitable to inoculate a soil rich in nitrogen; few nodules are formed under these conditions.

Cultures of nitrogen-fixing bacteria are not to be regarded in the light of nitrogenous fertilizers, increasing yields under all average conditions. The bacteria do not contain nitrogen. If conditions are favorable, they render nitrogen obtained from the air available for the legume.

WHEN INOCULATION WILL BE A FAILURE.

(1) If the directions are not studied intelligently and followed carefully.

(2) If the soil is acid and in need of lime. Liming to correct acidity is as important for the proper activity of the bacteria as for the growth of the plants.

(3) If the soil needs fertilizers, such as potash, phosphoric acid, or lime. The activity of the bacteria in securing nitrogen from the air and rendering it available to the legumes will not take the place of such fertilizing elements as potash and phosphorus.

It must be remembered that inoculation will not overcome results due to bad seed, improper preparation and cultivation of ground, and decidedly adverse conditions of weather or climate. Before attempt-

ing to inoculate a new crop, the farmer first should inform himself thoroughly concerning the proper handling of the crop itself; otherwise failure is almost certain. As an illustration, sowing alfalfa on hastily prepared land, on land foul with weeds, on acid soils, or soils underlaid with hardpan is contrary to accepted practice. Free publications covering the essential points in growing all common legumes may be obtained from the State experiment stations and from the United States Department of Agriculture.

KEEPING CULTURES FOR FUTURE USE.

The possibility of farmers keeping cultures from one year to another has been suggested. *This practice is not to be advised in any case.* For good results it is necessary to start with a fresh, pure culture. The pure culture, moreover, can be prepared only by a trained bacteriologist with laboratory facilities.

CONFUSION OF NEMATODE GALLS WITH NODULES.

Nematode galls, or root knots, are often mistaken for nodules, which they resemble in appearance. The nematode gall is extremely injurious, and in regions where it has been known to exist it is unwise to plant crops favorable to the development of the pest. Nearly all of the legumes should be avoided. This is important not only because the legumes susceptible to nematode attack are themselves injured, but chiefly because they furnish conditions favorable to the rapid development and multiplication of the nematode worms, and these may become a serious menace to succeeding crops or to orchard stock, which, under ordinary conditions, they would scarcely injure. There are, however, some resistant varieties[a] upon which the nematode worm can not develop, and in infested regions these resistant varieties should be used exclusively. If a leguminous crop with its roots covered with what are apparently nodules makes a sickly growth, or if there is doubt as to whether a legume is inoculated or infested with nematodes, samples for examination should be forwarded to the Department of Agriculture.

DANGER IN INOCULATION BY SOIL TRANSFER.

Very satisfactory inoculations have been obtained by transferring soil from old fields where legumes have been grown, but there are dangers incident to such soil transfer which should be noted.

[a] The most important and generally useful resistant variety is the Iron cowpea (*Vigna sinensis*). In the Southern States the velvet bean (*Mucuna utilis*) and Florida beggar weed (*Meibomia mollis*) are valuable.

The source of supply should be very definitely known, and in no case should soil be used from fields which have previously borne any crops affected with a fungous disease, a bacterial disease, or with nematodes. Numerous animal and plant parasites live in the soil for years and are established in so many localities that it is manifestly unwise to ship soil indiscriminately from one portion of the country to another.

Of scarcely less importance is the danger of disseminating noxious weeds and insect pests through this plan of inoculating by means of natural soils. Even though weeds may not have been serious in the first field, the great number of dormant seeds requiring but a slight change in surroundings to produce germination is always a menace.

If soil [a] is to be used, however, whether obtained from near-by fields or shipped long distances, the evidence should be clear that the soil is free from the objections mentioned above.

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[a] The amount of soil from a thoroughly inoculated field regarded as sufficient for inoculating an acre of land for alfalfa, for instance, is variously placed at 200 to 500 pounds.

FARMERS' BULLETINS.

The following is a list of the Farmers' Bulletins available for distribution, showing the number and title of each. Copies will be sent to any address on application to any Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C.

No. 22. The Feeding of Farm Animals. No. 24. Hog Cholera and Swine Plague. No. 25. Peanuts Culture and Uses. No. 27. Flax for Seed and Fiber. No. 28. Weeds: And How to Kill Them. No. 29. Souring and Other Changes in Milk. No. 30. Grape Diseases on the Pacific Coast. No. 32. Silos and Silage. No. 33. Peach Growing for Market. No. 34. Meats: Composition and Cooking. No. 35. Potato Culture. No. 36. Cotton Seed and Its Products. No. 37. Kafir Corn: Culture and Uses. No. 38. Spraying for Fruit Diseases. No. 39. Onion Culture. No. 41. Fowls: Care and Feeding. No. 43. Sewage Disposal on the Farm. No. 44. Commercial Fertilizers. No. 46. Irrigation in Humid Climates. No. 47. Insects Affecting the Cotton Plant. No. 48. The Manuring of Cotton. No. 49. Sheep Feeding. No. 50. Sorghum as a Forage Crop. No. 51. Standard Varieties of Chickens. No. 52. The Sugar Beet. No. 54. Some Common Birds. No. 55. The Dairy Herd. No. 56. Experiment Station Work—I. No. 57. Butter Making on the Farm. No. 58. 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